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NATURE

OF THE

PHYSICAL FORCES.

BY

EDWARD VOGEL.

Geheimnissvoll am lichten Tag,
Lässt sich Natur des Schleiers nicht berauben,
Und was sie deinem Geist nicht offenbaren mag,
Das zwingst du ihr nicht ab mit Hebeln und mit Schrauben.

GOETHE.

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FORCE,

Gravitation and Chemical Action.

I. FORCE.

The conclusions set forth in the present paper are based on the assumption that the hypothesis of the existence of an imponderable ethereal medium pervading all space is untenable, and that the phenomena hitherto referred to this imaginary agency are due to matter in a state of utmost attenuation, and the motion imparted to its ultimate constituents. As the ethereal hypothesis is at the present time the generally adopted base of science, I avail myself of the support of eminent physicists who have pronounced in opposition to it, and quote at some length the opinion of Sir W. Grove. Page 61 of his "Correlation of Physical Forces" contains the following: "In a lecture which I delivered in January 1842, I stated that it appeared to me more consistent with known facts to regard light as resulting from the molecules of matter itself, and not from a specific ether pervading it; just as sound is propagated by the vibrations of wood, or as waves are by water." Having called attention to the dependency of the transparency or opacity of a body upon its molecular structure, he continues, page 63:

"I cannot but think that it is a strong assumption to regard ether, a purely hypothetical creation, as changing its elasticity for each change of structure, and to regard it as penetrating the pores of bodies of whose porosity we have no proof; the which pores must, moreover, have a definite and peculiar communication also assumed for the purpose of the theory. The advocates of the etherial hypothesis certainly have this advantage, that the ether, being hypothetical, can have its character modified or changed without any possibility of disproof either of its existence or modifications.

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"I was not aware, at the time that I first adopted the above view and brought it forward in my lectures, that the celebrated Leonard Euler had published a somewhat similar theory, and though it has been considered defective by a philosopher of high repute, I cannot see the force of the arguments by which it has been assailed; and, therefore, for the present, though with diffidence, I still adhere to it. The fact itself of the correlation of the different modes of force is to my mind a very cogent argument in favor of their being affections of the same matter; and though electricity, magnetism and heat might be viewed as produced by undulations of the same ether as that by means of which light is supposed to be produced, yet this hypothesis offers greater difficulties with regard to the other affections than with regard to light. Thus, conduction and non-conduction are not explained by it; the transmission of electricity through long wires in preference to the air which surrounds them, and which must be at least equally pervaded by the ether, is irreconcilable with such an hypothesis. The phenomena exhibited by these forces afford, as I think, equally strong evidence with those of light, of ordinary matter acting from particle to particle, and having no action at a distance. The experiments of Faraday on electrical induction, showing it to be an action of contiguous particles, are strongly in favor of this view, and many experiments which I have made on the voltaic arc, are to my mind confirmatory of it." Thus far, for the present, Sir Grove.

The introduction of the hypothetical ether into science has, no doubt, been instrumental in arriving at great and inestimable results, but the existence of such a medium would seem to be a physical impossibility. Wherever there is a manifestation of force, a resistance is overcome; there must be a resisting object and an agent opposing and overcoming it. In other words, force is a product, not an independent, self-acting element; an object can resist and an agent overcome resistance only by means of support or of impulses imparted to them. An effect without a material medium conveying it, is unimaginable; ethereal or immaterial atoms would be wanting in that property, without which there can be no display of force; they could not repel each other nor ever come in contact and affect ponderable atoms, because they are devoid of the substance by means of which to resist and to attack. Attracting and repelling atoms of an imponderable or

immaterial ether seem, therefore, to be an incongruity in science.

I again quote Sir Grove: "One of the objections, he says (ibid. p. 64), to which this [i. e. the material] view is open, is the necessity involved in it of an universal plenum; for if light, heat, electricity, etc., be affections of ordinary matter, then matter must be supposed to be everywhere where these phenomena are apparent, and, consequently, there can be no vacuum. The answer appears to me to be, first, that we have no proof of a vacuum ever having been formed; the Torricellian, the most perfect with which we are acquainted, is filled with the vapour of mercury; Davy's experiments on this point prove, at all events, the formation of a vacuum to have been up to his time impracticable. Secondly, the other two theories equally suppose the non-existence of a vacuum; according to the emissive or corpuscular theory, the vacuum is filled by the matter itself of light, heat, etc.; according to the ethereal, it is filled by the all-penetrating ether. Of the existence of matter in the interplanetary spaces we have some evidence in the diminishing periods of comets, and where, from its highly attenuated state, we cannot test the character of the medium by which the forces are conveyed, we may, if we please, call such medium ether.

"At the utmost, our assumption, on the one hand, is, that wherever light, heat, etc., exist, ordinary matter exists, though it may be so attenuated that we cannot recognize it by the tests of other forces, such as gravitation. On the other hand, a specific matter without weight must be assumed, of the existence of which there is no evidence, but in the phenomena for the explanation of which its existence is supposed. To account for the phenomena the ether is assumed; and to prove the existence of the ether the phenomena are cited. For these reasons, and others above given, I think that the assumption of the universality of ordinary matter is the least gratuitous."

Faraday likewise entertained views tending to dismiss the ether but not the vibrations.

Confirmatory of the non-existence of a vacuum and the universality of matter, are the latest opinions of those physicists who assume that the so-called ether is only infinitely rarefied atmospheric air; or inversely, that our atmospheric air is nothing but the interplanetary medium condensed by gravitation on the surface of our planet.

This view seems to be correct, and the unlimitedness of the terrestrial atmosphere to be a physical necessity, in accordance with the kinetic theory of gases which is now generally adopted. The peculiarity of gas molecules is that they move freely in all directions, and quite independent of the influence of the central attraction of the earth. Were the interplanetary and interstellar spaces a vacuum, nothing would prevent the air molecules from diffusing with extreme rapidity into infinite space.

The atmosphere must, therefore, be continuous and unlimited, and the important conclusion follows that its effects must be equally so; *that consequently a pressure must prevail throughout the universe, enveloping and affecting all matter down to the minutest of its constituents.*

This pressure must be sufficient to counterbalance from without the tension of the terrestrial atmosphere, as likewise that of the atmospheres of all other heavenly bodies, and the known effect of the earth's atmosphere proves it to be of an enormous amount. It must also be uniform throughout, for a disturbance of the equilibrium in any part of the general or cosmic medium involves immediate restoration by a new distribution of the gaseous material and filling up of the gap.

The heavenly bodies, suspended in the general medium and surpassing it in specific gravity, offer resistance and points of support for the exercise of the pressure and condensation of the highly attenuated, and therefore, very compressible gas which is the substance of the cosmic medium must take place on their surfaces. This is, I think, the origin of all atmospheres, and the greater density of their lower strata, therefore, not due to an attraction residing in and proceeding from the centres of the bodies concerned, but the effect of the circumferential pressure of the cosmic medium. The simple explanation of gravity is thus arrived at; it is not a property inherent in matter and acting in a mysterious manner; no elementary self-acting unit; but as all force a product of different factors, an effect of the motion imparted and peculiar to all matter.

Such a conception of the nature of gravity is not inconsistent with what Sir Isaac Newton writes in his third letter to Bentley: "It is inconceivable, he says, that inanimate brute matter should, without the mediation of something else, which is not material, operate on and affect other matter without mutual contact, as it must do if gravitation in the

sense of Epicurus be essential and inherent in it, and this is one reason why I desired you would not ascribe innate gravity to me. That gravity should be innate, inherent and essential to matter, so that one body may act upon another at a distance through a vacuum, without the mediation of anything else by and through which their action and force may be conveyed from one to another, is to me so great an absurdity, that I believe no man who has in philosophical matters a competent faculty of thinking can ever fall into it. Gravity must be caused by an agent acting constantly according to certain laws; but whether this agent be material or immaterial, I have left to the consideration of my readers."

Faraday says on the same subject, in his article on the conservation of force: "For my own part, many considerations urge my mind towards the idea of a cause of gravity which is not resident in the particles of matter merely, but conjointly in them and all space."

Modern opinions have pronounced unreservedly and positively in favor of the view that gravitation is due to effects of pressure. I quote from an article "On the Transformation of Gravity," by James Croll, contained in the "Philosophical Magazine" for October, 1876. "It is now generally admitted," says the author, "that the conception of *attraction* does not represent the *modus operandi* of gravitation, because attraction implies action at a distance, or in other words, that a thing acts where it is not, which is just as impossible as that a thing can act *when* it is not. Gravity, in all probability, is of the nature of an impact or a pressure. Some of our most eminent physicists state that the force of gravity must either result from impact of ultramundane corpuscles, in some respects analogous to that of the particles of a gas (which has been found to be capable of accounting for gaseous pressure), or it must result from difference of pressure in a substance continuously filling space, except where matter displaces it.

"That gravity is a force of the nature of pressure is, I think, beyond all doubt; but that this pressure results from the impact of corpuscles or from a difference of pressure in a substance filling space, is purely hypothetical. Why not assume it to be a force without calling in the aid of corpuscles or a medium filling space?"

"pressure of the cosmic medium constitutes an omnipresent,
e, and is the only source and sum of all the forces of

nature; for whatever forces there are at work, they must affect and be represented by the general medium; and this is then the common stock of forces, the existence of which is involved in the fact of the conservation of energy; with the acknowledgment of this cause the fundamental and obscure problem of the nature of force is placed on solid ground.

As the cosmic pressure is due to gaseous bodies, the kinetic theory furnishes the data for the understanding of the processes and laws involved. The cause of the pressure of gases is generally attributed to the movements of the gas molecules, and due to the force with which these impinge on the walls of the vessels confining them. The source of the impelling forces is ascribed to the mysterious repelling action of the hypothetical, immaterial ether. I hold, immateriality being irreconcilable with any manifestation of force, that movement has been imparted to the constituents of matter from some source whose nature remains to be ascertained, and that the repulsion of gas molecules results from direct contact and collision.

In a given volume of a gas, innumerable identical molecules, moving freely in all directions, will meet and collide with a frequency proportional to the numbers present, the extent of the individual molecular surface and the velocity of motion. Under the influence of the impulses received in a unit of time, a molecule may be pushed in a certain direction with greater or smaller velocity and thus obtain a definite degree of momentum, or it may, in consequence of simultaneous shocks from opposite directions, come to a momentary stand-still, offering then to other molecules which may happen to strike it, a point of support or resistance. The general movements of gas molecules will be an unceasing tossing to and fro, alternate advancing and receding, an irregular oscillation or vibration in all directions and the mutual rebounding will produce the repulsive effect.

There are then three factors involved in the problem of force: space, matter, and motion. No special relation connects any particle of matter with any particular region of space; the power by which the molecules of matter move and constantly occupy successive different parts of space, can therefore be inherent neither in matter nor in space, but must have been imparted, constituting an independent element, which once present can never *be lost*, annihilated, or got rid of by any means; being like space

and matter, a definite given quantity, and like them, in its totality, unchangeable and indestructible.

Motion being the active principle, the particles of matter moved are the bearers, representatives, or units of force; presence of matter in space is equivalent to force; and this presence, the impulses being a given quantity, is dependent on the divisibility of matter.

The extreme divisibility of matter is revealed by the size of gas molecules, and follows as a necessary conclusion from the decrease of density of the atmosphere with the increase of altitude. The oxygen and nitrogen molecules of the air are not the ultimate constituents of matter, for hydrogen molecules are of smaller size; as, therefore, the rarefaction of the cosmic medium increases, a disintegration of the air molecules into their finer constituents must occur, till ultimately the finest constituents are reached. Such a disintegration can alone account for a uniformity of pressure; for diminution of the mass of the medium must be compensated by greater energy that is smaller size and greater velocity of the constituents.

A definite limit of divisibility is, however, a physical necessity; for if there was no limit, no line could be drawn between the finite, the discreet and circumscribed or the material; and the indefinite and formless; space and matter would be merged within each other, matter would be lost in space, or space be confounded with matter. The sameness of atoms in magnitude and form is evidence of the definiteness of divisibility, and this exact likeness and immutability of atoms constitutes the foundation of the uniformity of the laws of nature.

The extent of the actual divisibility of matter seems, on the other hand, to approach the very limits of the finite, as appears from the following data. Experience shows that the volume of gases is to the unit of matter contained in it as the square to its root; as this proportion must remain the same for all conditions, atoms will be in proportion to space as 1 : 4; if the cosmic medium in its utmost attenuation consists of a gas whose units of volume are atoms.

The determination of the size of molecules has been attempted by different methods, and the results agree in so far as to point to inconceivably small dimensions. Añaheim has concluded, from facts based on the coloring power of fuchsin and cyanin,

that the weight of the hydrogen molecule cannot exceed 0.000000000054 grams (1 gr.=15.43 grains); his molecules were in the liquid state, and he assumed only one molecule to be present in a drop of the colored liquid. But light or color can only be the effect of numbers or masses, and each liquid molecule must be composed of several gaseous ones. The above weight would, on these accounts, have to be reduced considerably.

Mr. Alex. E. Outerbridge, Jr., of the assay laboratory of the U. S. Mint at Philadelphia, passed powerful electric flashes between two slips of metal, and ascertained the loss of metal occasioned by 1000 or 3000 sparks by means of a balance sensitive to 1-1295 of a grain troy. Dividing this loss by the number of sparks, he found the loss volatilized by a single spark, each of which had given the complete spectrum of the metal, as follows: for gold 0.0000036 grain troy; for copper and silver 0.00000052; for nickel 0.00000026. (*Pop. Sci. Monthly*, May, 1877.)

According to the calculations of Lohschmidt, Sir Thompson and C. Maxwell, the weight of 200 million million million hydrogen molecules is 1 milligr. or 0.01543 grains troy. Accepting this result only as a rough guess, the above 0.00000026 grain nickel would represent 3370 million million hydrogen, and 58100000 million nickel molecules, the molecular weights of H and Ni being as 1:58.

The tension or volume of gases is, as has been stated, dependent on the rebounding of the gas molecules, and consequently proportional to their velocity, which, when the impulses are given quantities, is dependent on molecular mass and density. Mass and velocity are inversely to each other.

Assuming that there are none but compressing forces in nature, all the existing different kinds of molecules must be aggregates of atoms or compounds of such aggregates, held together by pressure. Molecular density, the effect of compression, must then be greater or smaller in inverse proportion to the mass compressed; for the compressing forces, though constant and unalterable, decrease with relation to a given center as the squares of distance increase; the maximum of density, therefore, will coincide with the minimum of mass, and for homogeneous substances density will be proportional to the square root of the mass. There may be, for instance, molecules composed of primary or atomic molecules, or of molecules of the first, second, third or

higher orders; the density of each will be the root of the mass, provided the mass be in each case referred to a common standard of value.

Elasticity is a manifestation of force, and as such no elementary unit; but atoms being impenetrable, and therefore the hardest and densest, and at the same time smallest of all bodies, must possess the highest degree of mobility and incompressibility, which involves the highest capacity for receiving and transmitting impulses. The elasticity of molecules, that is connected groups of atoms, follows as a necessary result from the intermittent character of the compressing forces which consist in the impulses of vibrating surrounding particles; under their action molecular constituents must themselves continue to vibrate in narrow limits, and can never be in permanent contact with each other. The conditions of elasticity, namely, mobility within certain limits, and capacity for resistance, are in this manner realized, and the elasticity of molecules will be proportional to the energy of the vibrations that is to molecular density.

The inverse relation between mass and density, or force, is of great importance, as will be seen from the following conclusions:

1. The tension or volume of gases must be inversely as their weight, and hydrogen, the lightest substance, represents accordingly the densest and smallest of all known molecules. This antagonism between mass and force accounts not only for the uniformity of the cosmic pressure by means of media of different weight, but also for the existence of a medium of so high a degree of elasticity as is requisite for the propagation of light through space with its known velocity.

2. The dependence of tension on molecular mass explains the occurrence of the liquid state; it will occur when the molecular weight of a substance equals the weight of volume of the surrounding medium. A still greater molecular weight will produce the solid state. There may be for one and the same substance different degrees of the gaseous as well as of the liquid and of the solid state. In each case, greater molecular aggregates are formed out of smaller, and consequently will, for one and the same substance, *the gaseous molecules be denser than the molecular aggregates of the liquid state, the liquid denser than the solid*, and so likewise with regard to the different degrees of each state.

All existing gaseous, fluid and solid bodies may be considered as immersed in the immense general or cosmic medium, which is composed of atoms or primary molecules, whose maximum density and force no force of any greater molecular aggregate can impede or arrest. Atomic vibrations must consequently pervade everything and prevail everywhere throughout the universe with no interruption in time or space; and the postulate of the mechanical theory of heat is thus placed on solid ground. It further becomes evident how light, as due to the vibrations of smaller molecules, can pervade and penetrate hard bodies, whose state involves lesser molecular density; how conduction and radiation of heat and light, and conduction of electricity, are possible, and how the ether, assumed on account of its supposed all-pervading property, can be dispensed with.

II. GRAVITATION.

The revolving of heavenly bodies around a common center and rotation on their axes is readily explainable as an effect of the cosmic pressure. These bodies are suspended or floating in the infinitely tenuous, ponderable medium which pervades space, and would perpetually remain motionless if they did not disturb each other by their presence. A body, of whatever magnitude and density, will remain perfectly at rest, as long as the forces by which it is surrounded and supported are exactly the same on all sides, for in every direction forces pressing from opposite sides will balance each other. But, as already stated, the incomparably light cosmic matter will, in proportion to the resistance encountered, undergo compression on the surface of the resisting bodies, and layers of condensed gases, atmospheres must consequently envelop all heavenly bodies, the mass and density of the latter determining the atmospheric depths and weights.

A body, A, at rest in the cosmic ocean, will be disturbed in its repose by the presence of another body, B, even at a considerable distance, if B is of large dimensions. The forces by which A is maintained in equilibrio will, on the side opposed to B, be intercepted to a greater or lesser extent, and the slightest diminution of support on this side will be sufficient to cause A to move in

the direction of diminished resistance and towards B, which itself will in the same manner be driven towards A.

In approaching, the atmospheres of the two bodies will meet and oppose further movement. The direction of least resistance is then in the circumference of B, and A taking this course will revolve around B and at the same time rotate on its own axis, the ponderable matter of both atmospheres constituting resisting media; while B will revolve and rotate likewise, but in opposite direction to A. Two perfectly or nearly equal masses of spherical form will in this manner revolve around each other and a common centre, while rotating on their own axes, with great regularity.

It is evident that at certain immense distances the influence that bodies are able to exercise on each other must cease or become imperceptible, and the existence of separate, more or less independent systems, as that of the sun with his planets and their satellites, is thus accounted for, while the revolving of such systems around larger centers is not excluded.

According to a statement recently made ("Popular Science Monthly," August 1877), it has been demonstrated by experiment that all bodies on the surface of the earth are heavier at midnight than at any other time of day, and that when new moon occurs at midnight this increase of weight is still greater. The confirmation of the occurrence of such a variation of gravity would be of great importance; its explanation follows directly from the conclusions of the nature of gravity set forth in the present paper. On the illuminated half of the earth the effect of the cosmic pressure is modified by the presence of the sun; it is indirect, acting through a heavier and less dense medium; while on the non-illuminated, the pressure is that of a medium of maximum density, and therefore, greater. At new moon, when the satellite is between the sun and earth, its pressure will increase the interception of forces on that side; while in all other positions it must have a similar effect on gravity as the sun, decrease of weight; and this will at new moon be eliminated from the rest of the terrestrial surface, involving an increase of gravity.

A direct and positive confirmation of the fact is, I think, afforded by the periodical, daily and yearly variations of the barometer. With relation to the daily variations, the average barometric hight is for all localities of the northern hemisphere, almost without exception, a maximum at midnight; and with

relation to the yearly, a maximum in the midst of winter, and a minimum in summer: in both cases the maximum coinciding with the opposition of the sun. The tension of the vapor of water to which the variations are generally attributed must, *ceteris paribus*, be a maximum at the time and season of maximum temperature, that is, at and about noon, and in summer, when the barometer is at its minimum: and a minimum at night and in winter, just when the barometer shows a maximum. The presence of water gas in the atmosphere can, therefore, not be the cause of the variations: and the influence of the position of the sun and moon relative to different localities on the surface of the earth, seems even to be in excess of the tension due to the presence of that gas.

That the ponderable cosmic medium cannot retard the movements of the celestial bodies needs hardly any mention, as the medium is itself the source of the motive power, and its influence the same for all.

The determination of the actual orbits of mundane bodies is, notwithstanding the simple cause of gravitation, a matter of great complexity, on account of the local and general causes by which it is modified. A local cause, which must influence the movement of the earth, is the unequal distribution of land and water over the northern and southern hemispheres, and a consequent irregularity of the effect of radiation of heat and light.

It is a well established fact of meteorology, that the effect of radiation is greater on land than on water: consequently, as the greater portion of the land is distributed over the northern hemisphere, the effect of radiation must be more powerful on the northern than on the southern hemisphere: and I think that this is the reason why the earth is farthest from the sun on the first of July, when the northern half of the globe faces the sun, and nearest on January first, when the southern half is in that position. Further investigation will probably show that the same cause determines, or has at least a great share in determining, the earth to proceed in its course round the sun in the ecliptic instead of parallel to the celestial equator.

III. CHEMICAL ACTION.

In an atmosphere, an object falls to the surface of the body enveloped by the atmosphere because forces are intercepted by the body, and the cosmic pressure is consequently greater in the direction toward the body than from it. The object falls when its mass is greater than that contained in an equal volume of the medium; it rises when its mass is smaller, and it floats when the respective masses are equal. In like manner is a smaller molecule driven towards a larger, and *vice versa*, because forces are intercepted by either, and the molecules move in the direction of diminished resistance. Chemical action is the gravitation or the fall of molecules on to each other. It is dependent on the gaseous or liquid state; that is, on freedom of molecular motion, and occurs between molecules of unequal mass, or between identical molecules by means of increase of velocity.

Chemical action being due to the cosmic pressure, no interpenetration or incorporation of substance occurs, but mere leaning or juxtaposition of the molecules against each other; and a smaller molecule has as little power over the mass of the larger as this has over the greater density of the smaller. Elementary molecules, therefore, come out intact from all chemical combinations. In a vacuum, the compression does not cease to exist with regard to the infinitely small molecules, because exhaustion can never exceed a certain point, and the elasticity of the medium increases with attenuation.

It is evident that, though atoms are all exactly of the same form, size and mass, molecules must differ in form according to their composition, and crystalization, is evidence that there are molecules and molecular aggregates of the most varied forms in existence.

The general means by which chemical action takes place is increase of molecular motion, which is increase of temperature, and the bringing together of molecules of different size or weight; another means is change of pressure.

The formation of primary molecules out of the ultimate constituents, the atoms, seems possible under the influence of retarda-

tion and acceleration of motion, resulting from indiscriminate collisions. Two atoms are able to support each other in two opposite directions, each being liable to displacement by atoms striking from other directions; for the mutual support in every possible direction of space, twelve individuals at least are required, the relation between diameter and the circumference of a sphere being as $1 : 4 \times 3.14 = 12.56$. Six pairs of atoms, balanced in every direction and forming a system of permanent stability, I call a primary molecule.

Primary molecules which may have formed within close distances will gravitate towards each other and gather. Their vibrations, under the accumulating impulses of the medium, will become more intense in proportion to the mass or numbers of molecules assembled, and the velocity must finally attain to a degree sufficient to effect the union of two colliding identical molecules and the formation of a molecular aggregate or new molecule. The process by which this is accomplished consists in the compression resulting from the collision, and the closing in of the surrounding medium upon the connected mass. In this manner molecules of the most varied kind may be produced, and seems the collection of greater and even immense masses possible.

Two effects are always involved in chemical action, to wit, change of molecular mass and change of molecular density. When a molecular mass is increased by the accession of another molecule, its inertia or power of resistance in space is likewise increased in exact proportion to the accession; and this acquired power of resistance is the means and measure of a simultaneous increase of compression which the mass undergoes, and which results in an increase of density and velocity, the opposite of the effect of increase of mass; so that the two effects always concur and compensate each other. It follows from this that the new molecule can never be, as is now erroneously assumed in chemistry, simply the sum of the combining weights.

Two different modes of chemical combination may take place between two identical molecules according to the greater or lesser degree of force with which they are impelled against each other.

For instance, two molecules, each of a mass=0.32, may meet either with the forces $\frac{1}{0.32}+\frac{1}{0.32}$ or with the forces $0.16+0.16$. By the first mode, primary molecules and the different gaseous, liquid, and solid aggregates of one and the same substance are formed.

The elements for the determination of the value of a new molecule, are: 1, the sum of the combining masses; and, 2, the amount of compression or reduction of volume. The latter is always one half of the sum of the colliding forces. The total weight of the mass contained in the two united molecules, is to be referred to the new volume. By dividing the square root of the weight of volume by the square root of the weight of total mass, a quotient is obtained indicating the density or unit of mass referred to the density or unit of a mass corresponding to the new volume, and the product of the sum of weights by this quotient is the molecular weight.

These relations are expressed by the following formulæ:

n=number of molecules of an aggregate; p=molecular weight; v=molecular volume;

$$\text{impelling forces}=\frac{1}{p}+\frac{1}{p}\ldots\ldots\ldots 1)\ np-2n-2=v.$$

$$\text{impelling forces}=\frac{p}{2}+\frac{p}{2}\ldots\ldots\ldots 2)\ (p+p)-\frac{p}{2}=v.$$

m=sum of weights of the masses contained in the combining molecules; d=molecular weight of the new molecule.

$$3)\sqrt{\frac{v}{m}}\times m=d.$$

If the velocity of atoms whose mass is a minimum and=0.01 is =1.00, the velocity g of a molecule of any weight d will be

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4)\ \frac{1}{d}=g,$$

and velocity being equivalent to power of tension or molecular density, the molecular volume is.....5) $g^3=t$.

IV. COMPUTATION OF THE MOLECULAR WEIGHTS OF THE EXISTING GASEOUS ELEMENTS FROM ATOMIC COMPOSITION.

So far my exposition has consisted in general conclusions and plausible assumptions, supported by acknowledged facts; I now produce positive proof of their substantial correctness by calculating, in accordance with the formulæ just exhibited, the exact molecular weights of the principal elements.

If the power of resistance in space of 12 atoms is 1-12, they will be acted upon by an equal force from without and be compressed by a force=2-12. The increase in weight being=1-12, the unit of volume and mol. weight of primary molecules will be=11.5, if 1 atom is=1; or=0.115 if the unit is 0.01.

The hydrogen molecule is an aggregate of 3 primary molecules.

Value of the H molecule:

$$3\times 11.5-4 \ldots\ldots\ldots\ldots v=30.5$$

$$\sqrt{\frac{30.5}{36}}=\frac{5.523}{6}=0.9205\times 36 \ldots\ldots\ldots\ldots d=33.138$$

$$\frac{1.0000}{0.33138} \ldots\ldots\ldots\ldots g=3.0177$$

$$3.0177^2 \ldots\ldots\ldots\ldots t=9.1065$$

The carbon molecule consists of 4 primary molecules compressed by forces $\frac{p}{2}+\frac{p}{2}$.

Value of the C molecule:

$$2\times 11.5-2 \ldots\ldots\ldots\ldots v=21$$

$$\sqrt{\frac{21}{24}}=\frac{4.5825}{4.8989}=0.9354\times 24 \ldots\ldots\ldots\ldots d=22.4496$$

$$22.4496+\frac{22.4496}{2}=(p+p)-\frac{p}{2} \ldots\ldots\ldots\ldots v=33.6744$$

$$\sqrt{\frac{33.6744}{48}}=\frac{5.809}{6.9282}=0.839\times 48 \ldots\ldots\ldots\ldots d=40.272$$

$$\frac{1.0000}{0.4027} \ldots\ldots\ldots\ldots g=2.483$$

$$\ldots\ldots\ldots\ldots t=6.165$$

The nitrogen molecule is an aggregate of 4 primary molecules.
Value of the N molecule:

$$4\times 11.5-6 \ldots\ldots\ldots\ldots\ldots v=40$$

$$\sqrt{\frac{40}{48}}=\frac{6.33}{6.93}=0.9134\times 48 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots d=43.84$$

$$\frac{1.0000}{0.4384} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots g=2.281$$

$$2.281^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots t=5.203$$

The oxygen molecule is an aggregate of 6 primary molecules.
Value of the O molecule:

$$6\times 11.5-10 \ldots\ldots\ldots\ldots\ldots v=59$$

$$\sqrt{\frac{59}{72}}=\frac{7.681}{8.486}=0.9051\times 72 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots d=65.1672$$

$$\frac{1.0000}{0.65167} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots g=1.5345$$

$$1.5345^3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots t=2.3547$$

The chlorine molecule is an aggregate of 18 primary molecules.
Value of the Cl molecule:

$$18\times 11.5-34 \ldots\ldots\ldots\ldots\ldots v=173$$

$$\sqrt{\frac{173}{216}}=\frac{13.15}{14.7}=0.89456\times 216 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots d=193.22$$

$$\frac{1.0000}{1.9322} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots g=0.5175$$

$$\frac{1.9322}{0.5175} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots t=3.7333$$

Bromine and iodine, which are not included in the list, have both, I think, the same molecular mass, differing in the same manner as N and C; both being composed of 2 Cl molecules, Br$=(p+p)-\frac{p}{2}$, and I$=(p+p)-2$.

H being taken as a unit, the molecular weights of these elements are:

H, $d=33.138=1.000$	O, $d=65.167=1.9666$
C, $d=40.272=1.2156$	Cl, $d=193.22=5.831$
N, $d=43.84=1.323$	

g and d being inversely to each other, the product by both is a constant, and all molecules as such products are equivalents, and may be substituted for each other, a fact established and accepted in chemistry. The value of $g\times d$ is for all molecules$=3.0177$.

As all molecules are equivalents when both the volume and weight of the respective gases are considered, the difference between equal volumes of different gases is that of weight of volume, and if submitted to bear the weight of many volumes of gases of whatever kind, the effect of the pressure will be that of the weights of volume. The weight of the mol. volume of gases is equal to the square root of the volume, or to the quotient of density by molecular weight, $e=\frac{g}{d}$ and the weight of H being taken as a unit for the calculated molecules as follows:

H, $\frac{3.0177}{1}=3.0177$, $e=1000$

C, $\frac{2.483}{1.2156}=2.0426$, $e=1.477$

N, $\frac{2.281}{1.323}=1,724$, $e=1.75$

O, $\frac{1.5345}{1.966}=0.78$, $e=3.866$

Cl, $\frac{0.5175}{5.831}=0.08875$, $e=34.00$

The numbers of the last column are the squares of the molecular weights, for $1.2156^2=1.477$; $1.323^2=1.75$; $1.966^2=3.865$; $5.831^2=34$.

The close connection of these weights with the established chemical equivalents is apparent from the following figures:

CHEM. EQUIV.

C, $d=1.2156\times 2=2.4312\times 1.41=3.428$; $3.428^2=11.75$; C=12.

N, $d=1.323\times 2=2.646\times 1.41=3.73$; $3.73^2=13.91$; N=14.

O, $d=1.966\times 2=3.932$; ..... $3.932^2=15.46$; O=16.

Cl, $d=5.831$; ..... $5.831^2=34.00$; Cl=35.

For C and N twice the molecular weight has been multiplied b

1.41: the explanation of this proceeding is that weights of tensi

and of $N=2.646^2$ are doubled under atmosphe

the weight of tension is equivalent

$\sqrt{2}=1.41$. The weigh

that of a

The atmospheric pressure is that of volume weights of N and O, and must be made up by equal or nearly equal weights of each, as otherwise they could not form an everywhere uniform mixture. It is a multiplum of 7 N+7.73 O=14.73, representing 2 vol. of N, or $4\times1.75=7$, and 1.5 vol. of O, or $2\times3.866=7.73$ ($=1.966\times\sqrt{2}=2.781^2$), a total of 3.5 vol., weighing 14.73.

When volumes of the different gases are submitted to pressure, it must in every instance be multiples of the molecular volumes which are present; and to resist or balance a certain amount of pressure a corresponding weight has to be made up by volumes of each gas, and the effect of pressure will count in accordance with the number of volumes pressed upon. The pressure of a weight=14.73 will reduce a volume of half that weight to one half; so that by the atmospheric pressure, numbers of volumes of the different gases weighing 7.365, or nearly so, will each be increased in weight to its double, and the explanation is thus given why in the above instances the weights of C and N, but not those of O and Cl, have been multiplied by 1.41.

The atmospheric pressure is not exactly=14.73 with relation to the mol. gas volumes, for N=7 will undergo compression by O=7.73, or a force $7.73\div7=1.1043$. The result of this compression will be a change of the volume of N; but as the greater and compressing weight of O is within the larger and not confined volume of N, tension being inversely to weight, the effect will be not a reduction, but an expansion of the volume of N. A force= 0.1043 will produce an expansion of $0.2086\times7=1.46$, corresponding to a diminution of weight=0.73 for the 2 vols. of N represented by 7, or of 0.365 for one volume.

When the weight of N is determined, the volume serves as a measure of value, and the two enlarged volumes of N will therefore continue to have their original weight=7, while the weights of the molecular volumes of other gases, in order to compare with N, have to be increased in proportion to the enlargement; this being taken at 0.1 of the calculated value, or=0.0365, the exact weights of volume, identical with the established chemical weights, are obtained as follows:

H has a greater power of tension than the compressing media, and remains therefore unaltered..... H= 1.000

The weight of 2 vol. of N=7, doubled under atmospheric pressure..... N=14.00

The tension of N is with relation to C only $1.477 \div 1.75 = 0.844$; in proportion to this greater tension is the increase of weight of C on account of the enlargement of the vol. of N to be diminished; it is therefore $0.844 \times 0.0365 = 0.0308$; $1.0308 \times 1.477 = 1.522 = 1$ vol.; $1.522 \times 4 = 6.088 = 2$ vol.; doubled by atmospheric pressure..... C=12.176

1 vol. of $O = 3.865 \times 1.0365 = 4.006 \times 4 = 2$ vol..... O=16.024

1 vol of $Cl = 34 \times 1.0365$..... ..... Cl=35.240

There are in the air mixture of 3.5 vols., 2 vols. of N;

$2 : 3.5 = 0.5714 \times 0.0365 = 0.020856 \times 14.73 = 0.3072$;

14.73—0.3072 ..... weight of air=14.423

The oxygen of the air being, in consequence of the compression of N, distributed over a larger space, its weight, with relation to a volume of air, is diminished in proportion to the increase of the volume of N.

The increase of weight by 0.0365 instead of 0.365 has no other significance than that the relation of the weight of pressure to the calculated molecular weights is as 10 to 1; and not the actual amount of atmospheric pressure has been established, but only the relative, and the connection or real identity of the calculated molecular weights with the established values of the chemical equivalents.

The volume of gases is made up of innumerable units of weight, that is of single molecules, each of which counts as its square with relation to the gas volume; the chemical equivalents represent the volume weights of equal numbers of units of the different gases, and the relation of units for the gases in question is as follows:

UNIT OF NUMBERS.

$N=14$, weight $\sqrt{14}=3.74$; $\frac{3.74}{1.323}=2.827$ ..... $2.827^2=8.000$

$C=12$, weight $\sqrt{12}=3.464$; $\frac{3.464}{1.2156}=2.849$ ..... $2.849^2=8.00$

$O=16$, weight $\sqrt{16}=4.00$; $\frac{4.00}{1.966}=2.035$ ..... $2.035^2=4.00$

$Cl=35.5$, weight $\sqrt{35.5}=5.96$; $\frac{5.96}{5.831}=1.022$. ..... $1.022^2=1.00$

The units have been stated in round numbers, without regard to the small differences which are due to the difference of volume occasioned by atmospheric pressure.

A better insight into the nature of valency is obtained, when, as is done in chemistry, the weights of equal tension, instead of their square roots, are taken for the determination of the value of volumes.

The weights of tension are:

$$H=\frac{9.1065}{1}=9.1065 \qquad O=\frac{2.3547}{1.9666}=1.1973$$

$$C=\frac{6.165}{1.2156}=5.0716 \qquad Cl=\frac{3.7333}{5.831}=0.64$$

$$N=\frac{5.203}{1.323}=3.932$$

The weight of tension of H being taken as a unit, the weights of equal tension are:

$$H=\frac{9.1065}{9.1065}=1.0000 \qquad O=\frac{9.1065}{1.1973}=7.6059$$

$$C=\frac{9.1065}{5.0716}=1.795 \qquad Cl=9.1065\times 1.933=\frac{17.5956}{0.64}=27.5$$

$$N=\frac{9.1065}{3.932}=2.316$$

The weight of tension of N is to that of O as 2.316 to 7.6059 or as 1 to 3.284, that is, the tensive power of N is 1, while that of O is only 1-3.284. One part by weight of N fills the same space as 3.284 parts of the weight of O, and as space that is volumes or equivalents of tension are the measure of value, the weights must be as the tensions and are actually found to be so in the air mixture which contains in 100 parts by weight 76.7 N and 23.3 O or 3.292 to 1. The weight of volume of O is by atmospheric pressure increased by 0.0365; there are represented in the weight of 7.6059 O, $7.6059 : 1.966 = 3.87^2 = 15$ units of volume. The increase for one is, therefore, $0.0365 : 15 = 0.00243$; and the proportion is then 1 to $3.284 \times 1.00243 = 3.29198$, or exactly as found by experiment.

3 equivalents of tension of N, or $3 \times 2.316 = 6.948$, have nearly the weight of 1 O=7.606; they represent, when doubled by atmospheric pressure, the chemical weights N=14 and O=16, of which the former combines with 3, the latter with 2 H, that is, in addition to the equivalents of tension, which themselves represent multiples of the molecular volumes for $2.316 : 1.323 = 1.75 = 1$ $7.6059 : 1.966 = 3.87 = 1$ vol. O; that is, the equivalents

of tension, referred to the molecular weights as units, express molecular volumes. It is, therefore, proven that chemical combination takes place between single molecules; and valency expresses the number of molecular units contained in the volumes of the different gases which enter into combination. C, whose molecule has the same mass as that of N, is accordingly not tetra, but tri-valent, and the proportion in which H and C are by analysis found in the two principal compounds is indeed a multiplum of 3, marsh gas containing 3, olefiant gas 6 H to 1 C. There are then represented

By	H = 1,	1 mol.	unit.
"	C = 12,	3 "	"
"	N = 14,	3 "	"
"	O = 16,	2 "	"
"	Cl = 35.5,	1 "	"

Some hitherto unexplained phenomena are easily understood with the knowledge of the true molecular weights of C and N. C is, with relation to its molecular mass, the densest of all terrestrial bodies, that mass, though almost a minimum, being compressed into two-thirds of its original volume, and this absolutely and relatively great molecular density accounts for all the properties of carbon; its non-existence in the gaseous state; the variety of its allotropic modifications; the density, hardness and refractive power of the diamond; the value of carbon as a combustible material; its importance as a constituent of organic bodies, likewise on account of its substantiality and small molecular weight, both of which properties afford also the explanation of the band spectrum of C.

The explosive properties of the nitrogen compounds find a ready explanation in the great power of tension of N, which is 1÷1.75, the maximum=1 being represented by the tension of H.

As follows from my deductions, Mariotte's law does not take into account an essential fact concerned in the relation between volume and pressure, viz: that the density of volume is as the square of the weight of tension, divided by the molecular weight; and relation which exists between volume and molecular entirely ignored in that law.

V. THE LAW OF AVOGADRO.

This law or rather hypothesis is the great and fundamental error of modern chemistry; and that so enormous an incongruity as it involves has, in the midst of the most brilliant achievements of the science, obtained so general an acceptance, seems truly astonishing. On its ground it is assumed that equal numbers of molecules are contained in equal volumes, and the molecular weights are consequently identified and confounded with the weights of tension. The irreconcilability of this assumption with the kinetic theory of gases proves it to be utterly inadmissible, the essential fact of that theory being that gas volumes are determined by molecular velocity, and must, therefore, be counted by squares in relation to the molecular units counting only as such; and that they count inversely, volumes increasing when the molecular weights diminish, and *vice versa*.

Molecules are not equivalents of tension, they are equivalents only as products, $g \times d = 3.0177$; tension alone can, therefore, afford no foundation for the determination of the number of molecular units.

In the case of all vapors which are not permanent gases, namely, those of As, P, Hg, S, Cd, NH^4Cl the discrepancies are acknowledged and constitute unexplained exceptions to the rule. But the incongruity is most obvious in the general conclusion that a molecule is composed of 2 atoms, 1 atom to represent 1 volume, and 2 atoms 1 molecule and two volumes; for if one atom is 1 volume, 2 atoms or a double weight can have only $\frac{1}{4}$ of a volume, while on the other hand, 1 vol.+1 vol. are not 2 vol. with reference to the molecular weight, this being $\sqrt{2}=1.41$. The established molecular weights of all compounds, as far as correct, are, accordingly, so not on account but in spite of the law.

Cl=35.5 and H=1 combine and form 2 volumes of HCl, but 1 volume of this, or $36.5 \div 2 = 18.25$, is not the weight of tension of hydro-chloric acid; for, if by the combining volumes molecular [illegible] are represented, as is really the fact, the two resulting [illegible], and not their half, must represent the tension of HCl, as they contain HCl molecules, and none but such, and correlated to the standard volume; HCl is, therefore, =36.5.

The hypothesis is likewise irreconcilable with the phenomena of temperature and change of volume, which are invariable concomitants of all chemical action. It involves the assumption that only a portion of each molecule of a substance is exchanged for a portion of a molecule of the other substance when combination takes place. For instance, in the formation of the two volumes of HCl, it is presumed that the number of the HCl molecules is the sum of those contained in the two combining volumes, and, to account for this, it is further presumed that the H and Cl molecule is each =2 atoms, which, being separated by chemical action, 1 atom of H combines with 1 atom of Cl, while 1 atom of Cl goes to take the place vacated by 1 H atom.

If this were the true nature of chemical processes, association would always be attended with corresponding dissociation, the effects ought, therefore, in every case, to compensate and neutralize each other, and no change of volume or of temperature could occur. The fact is that they are never wanting in any case of chemical action, and on account of this irreconcilability with obvious facts, the hypothesis admits of no explanation of the phenomena in question, which, therefore, have remained a mystery. The explanation is simple with its dismission. First, as to the increase of temperature, it will be shown that it results from increase of molecular mass and density; and, second, change of volume is change of tension, and results from change of molecular mass and density. One volume of a gas combines with one or several volumes of another, and the result is, in most instances, 2 volumes of the compound. The reason of this is, that, when 1 volume combines, it can do so only with an equivalent, and this may be represented by 1, 1.5, 2, 3 or more volumes of another substance, molecular equivalents not being identical with equivalents of tension; the fact that the tension of the equivalent is reduced to the tension of the 1 volume, proves that the accession of mass to the molecule of the latter must be compensated by a corresponding compression or increase of molecular density; if this was not the case, the result could not be a multiplum of the weight of tension of the 1 volume, for increase of molecular weight without increase of molecular density is equivalent to diminution of tension.

The actual composition of compounds is by this conclusion disclosed; for if the accession of the mass of one molecule to that

of another is also the measure of the compression of the molecule whose mass is increased, the nature of the processes which constitute the chemical action is accurately defined. This is in agreement with the general principle set forth in the chapter on "chemical action." The molecular weights of some of the principal compounds calculated accordingly, are as follows:

The accession of mass to the greater molecule being the measure of its compression, the impelling forces correspond to the formula $(p+p)-\frac{p}{2}=v$, p being the mass of the smaller molecule, and one p to be replaced in the sum by the mass of the larger one.

HN. $N=43.84$; $H=33.138$; $43.84+\frac{33.138}{2}=v=60.409$

$$\sqrt{\frac{60.409}{84}}=\frac{7.772}{9.165}=0.848\times 84=d=71.232$$

$$\frac{1.000}{0.7123}=g=1.404$$

$$\frac{3.0177}{1.404}=w=2.15$$

$$2.15^3=t=4.6225$$

HO. $O=65.1672+\frac{33.138}{2}=\ldots\ldots\ldots\ldots\ldots v=81.7362$

$$\sqrt{\frac{81.736}{108}}=\frac{9.04}{10.392}=0.87\times 108=d=93.96$$

$$\frac{1.000}{0.9396}=g=1.0643$$

$$\frac{3.0177}{1.0643}=w=2.835$$

$$2.835^3=t=8.037$$

CO. $C=40.272$; $O=65.1672+\frac{40.272}{2}\ldots\ldots v=85.303$

$$\sqrt{\frac{85.303}{120}}=\frac{9.236}{10.954}=0.843\times 120=d=101.16$$

$$\frac{1.0000}{1.0116}=g=0.9885$$

$$\frac{3.0177}{0.9885}=w=3.0528$$

$$3.0528^2=t=9.319$$

[illegible] is an exception to the rule that 1 volume combines with an equivalent, and that the product is=2 volumes; for O=16=1 volume combines with the requisite quantity of C and forms 1 volume [illegible] and O=8=½ volume combines with an equivalent [illegible] and the result is ½+½=1 volume; or 1 volume O=16+1 volume O=8=2 volumes of CO^2=44.

[illegible] $\frac{\text{O}=100.25-33.1572}{2}$ = ... v=133.7436

$\sqrt{\frac{133.7436}{192}}=\frac{11.5758}{13.8564}$=0.8346×192=$d$=160.243

$\frac{1.0000}{1.60243}=g$=0.6157

$\frac{3.0177}{0.6157}=w$=4.9

$4.9^2=t$=24.01

[illegible] is an instance of a compound whose base is a radical. There is nothing to prevent CO nor CO^2 to combine with other molecules and give rise to more complex radicals. The combination [illegible] is known; and as Cl =193.22 combines with H, [illegible] will undoubtedly do so too. It is from this, apparently, that the barrier which separates organic and inorganic compounds is an artificial one.

When H and Cl combine, no reduction of volume occurs; the mass of the Cl molecule must, consequently, be twice compensated by compression, making the volume =Cl+H−2H.

[illegible] Cl=193.22−33.138 ..... v=160.082

$\sqrt{\frac{160.082}{252}}=\frac{12.6523}{15.8745}$=0.797×252=$d$=200.844

$\frac{1.0000}{2.00844}=g$=0.4979

$\frac{3.0177}{0.4979}=w$= 6.061

$6.061^2=t$=36.735

By the action of atmospheric pressure molecular units are [illegible] into less space; their relative value to each other is not [illegible] to a slight extent, in consequence of the preponderance of the weight of O over that of N in the air mixture.

But when, on analysis, 8 parts by weight of O are found to 1 part of H in water, the molecular weight represented by O is $=\sqrt{8}=2.828$, that is, 1.966×1.41 or nearly that of the weight of 1.5 molecules; which shows that the generally accepted weight of the compound is not that of a molecular unit.

The connection between the calculated and the accepted weights, of which the former express molecular volumes, the latter equivalents of tension, is as follows:

N=14 represents multiples of 3 mol. units.....HN	$\frac{17}{3}$	5.66
calculated....		4.62
O=16 represents multiples of 2 mol. units.....HO	$\frac{18}{2}$	9.00
calculated		8.00
C=12 represents multiples of 3 mol. units.....CO	$\frac{28}{3}$	9.33
calculated....		9.319
CO^2 represents a multiple of 1 mol. unit.....		22.00
calculated....		24.01
HCL represents a multiple of 1 mol. unit.....		36.50
calculated ...		36.735

Leaving the accuracy of the computed values to be determined by further investigation, my statements concerning Avogadro's law are fully vindicated in the case of HCl where only one molecular unit is represented, the calculated weight being almost exactly such as I have concluded and maintained it to be.

There remains of chemical phenomena to be mentioned that of chemical affinity. That this depends on the absolute and relative molecular mass and density and their proportion between two combining molecules is self-evident, and to be inferred from the influence which light of short wave length has in effecting the union of Cl and H molecules, which does not occur in the dark, but with violent explosion when a mixture of the gases is exposed to sun light, the violet light or the more refrangible part of the spectrum proving the effect. The explanation is that the vibrations of the smaller molecules, the mass of which, being communicated to the [illegible] increase the velocity of their molecules, which, [illegible] time is allowed to accelerate so that at the [illegible] considerable increase of velocity [illegible]

tion is by these means realized. That H does not combine generally with the metals, while O does, is another evidence of the fact that a certain proportionality between molecular masses constitute weak or strong affinity, and the preference of union manifested by different substances toward each other when in a mixture, will doubtless prove of value for the determination of the exact molecular weights of liquids and solids.

In order to understand how different non-gaseous substances can decompose each other, it is to be remembered that all molecules and their constituents are in never-ceasing oscillating motion, and that in this state dislodgment of particles may take place just as well as when combining molecules are in the free state.

VI. SPECTRAL LINES—THE LAW OF DULONG AND PETIT.

The molecular impulses emitted by the sun constitute the general source of heat and light on earth, and the temperature of all bodies is, in the last instance, due to this cause. The common source of heat for all terrestrial bodies admitted, the explanation of the decrease of the temperature of the atmosphere with increasing altitude is to be found in the fact that accumulation or concentration of matter is essential to the production of heat and light, atmospheric matter being the more rarefied the greater the distance from the earth's surface.

Why accumulation of matter is an essential element in the phenomena of heat and light is readily perceived. According to the degree of concentration, more or less numerous points of attack are offered to the impulses of the surrounding medium; from the uninterrupted succession of the impulses result the greater forces required to move geater masses, time in which forces accumulate, becoming a factor; the molecular vibrations restricted within narrow limits increase in velocity, and their amplitude or the wave length is thus determined by the presence of matter in a greater or lesser state of concentration. With the effect of the same impelling forces, the quality of heat and light produced will depend on the nature of the substances acted upon. The

whole process is justly compared to a bombardment, the missiles as also the objects struck being the molecules of all sizes. Heat results from the vibrations of larger, light from those of smaller molecules. Larger molecules may bombard smaller and inversely; the effect always tells, and heat and light are consequently convertible into each other; but the force of the denser (smaller) is greater than that of the larger molecules, force being in inverse ratio to mass, and the bombardment of several smaller against a larger molecule will be more effectual than inversely, so that with the accumulating impulses of the former the heavier aggregates are first put in motion, and red light is always the first effect of increase of temperature; while the continuance of the accumulation of impelling forces will gradually overcome the resistance of the smaller and denser molecules. The different shades of heat and light are in this manner and under the proper conditions produced by means of all substances and all impulses.

There is a minimum of matter for a given space producing a minimum of light, which is represented by the bright lines of glowing gases, millions of millions of molecules co-operating, however, in the production of each single line; and as minimum of mass involves maximum density, these lines are closely connected with molecular weight. I have shown (Sci. Amer., 27 Nov. '75) that the bright lines of the hydrogen spectrum follow each other at distances which are squares of three, to wit:

The wave-lengths of the H spectrum are, according to Angstrom, in 0.0000001 millimetres: 41012, 43400, 48606, 65618; distance from line to line: 2388, 7594, 24606. These distances, referred to the shortest wave-length as a common standard of value are: $\frac{41012}{2388}=17.1742$; $\frac{41012}{7594}=5.7247$; $\frac{41012}{24606}=1.9082\times3=5.7246\times3=17.1738$. And 3, or very nearly 3, (3.0177) is, as derived from my calculations, the molecular unit of H.

I have succeeded in establishing likewise the nature of the composition of the oxygen spectrum. It is composed of ten groups, each group consisting of three lines, which also succeed each other at the rate of squares of 3. The following figures are those of Mr. Huggins' air spectrum. The lines forming a group are marked with the same letter; the groups are: *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, *k*; the succession of lines in each group is indicated by the numbers 1, 2, 3:

a^1 1678	a^2 2119	f^2 2563	i^2 3238	e^3 4059
b^1 1699	b^2 2145	h^1 2597	k^2 3241	f^3 4087
c^1 1737	c^2 2181	g^2 2626	a^3 3395	g^3 4232
d^1 2043	g^1 2213	i^1 2748	b^3 3456	h^3 4395
e^1 2060	d^2 2502	k^1 2766	c^3 3560	i^3 4615
f^1 2089	e^2 2512	h^2 3086	d^3 3710	k^3 4639

Group *b*, for instance, is composed of the lines 1699, 2145, 3456; the distances, referred to the shortest wave-length, are: 1699÷446 =3.81; 1699+1311=1.296×3=3.888. The agreement is far from being as exact for the different groups as in the case of H; but there can be no doubt that the relation of lines is such as stated.

The nitrogen lines of the same spectrum I have found offering still greater discrepancies when arranged into the proper groups, and think that the spectral lines of the pure gases will show better agreement than those of the air mixture, in which N, notwithstanding its lesser molecular weight, is represented in the proportion of 3.292 to 1 O. The subject, and the conclusions to be derived, are therefore left to further elucidation.

Spectral lines being indicative of the maximum density and small molecular mass of gaseous molecules, bands will probably be found to be due to greater molecular mass and great concentration; while the continuous spectra, as is well known, are those of the greater aggregates of the solid state, and represent lesser molecular density.

Heat and light being nothing but effects of molecular motion, a close relation must exist between g, which represents molecular velocity, and s, specific heat, which expresses the amount of force requisite to produce identical states of molecular motion in different substances; and as molecular motion depends on molecular mass, s must stand to d exactly in the same relation as g, specific heat and molecular density must be, if not identical, proportional to each other. This is Dulong and Petit's law, which, therefore, is well founded in fact, and according to which s is inversely as the atomic (molecular) weight, and the product by both a constant, in the same manner as for all molecules $g \times d$ is=3.0177. The constant $s \times d$ is indeed but slightly different from this magnitude, for the specific heat of H is =3.41 (Regnault, Wiedeman), $d=1$; consequently $s \times d=3.41$. H representing the maximum of molecular density, represents also the maximum of specific heat, for the specific heat of H is greater than that of any other known substance.

Weight referred to specific heat will express the relation to molecular weights only in so far as the quantities whose specific heat is determined express molecular units; when sums and multiples of volumes are represented, the specific heat is so likewise, and the great service derived from the law in the determination of the molecular weights of solids is due to the fact that chemical equivalents have served as a base. In the case of gases, where this is not so, the coincidence has not been established.

The molecular densities referred to that of H express the relative molecular weights; the molecular weights of the elementary gases arrived at in the same manner by reference to the specific heat of H are as follows:

H, $s=3.41$; O, $s=0.2182$; $\frac{3.41}{0.2182}=16$; N, $s=0.244$; $\frac{3.41}{0.244}=14$; Cl, $s=0.1214$; $\frac{3.41}{0.1214}=28$.

The weights of volume of these gases are H, $e=1$; O, $e=\sqrt{16}=4$; N, $e\sqrt{14}=3.74$; Cl, $e\sqrt{35.5}=5.96$; to which the above weights correspond very closely, for H, $3.41=4\times1$; O, $16=4^2$; N, $14=3.74^2$; Cl, $28=5.96^2$ the discrepancies being due to the following circumstances:

O=16 represents 2 equivalents of tension, and as specific heat is inversely as mass, that of a weight=16 is less relatively than that of a weight=8; the molecular weight of H being only half as great as that of O, its specific heat must be twice as great as that of the latter, and 3.41 represents, therefore, compared with O=16, only 1 equivalent: $\sqrt{16}=4$; $\sqrt{8}=2.8284$; $2.8284\div4=0.707$; 4 reduced in proportion to half the difference, or $0.293\div2=0.1465$, is $0.8535\times4=3.414$, that is equal to the specific heat of H.

1 equivalent of Cl is=35.5; specific heat being inversely as mass, $s=0.1214$, corresponding to a mass=28, will be smaller relatively to a mass=35.5. The molecular weight of Cl referred to the specific heat of H is $3.41\div5.831=0.585$; d is to g or s, with relation to a fraction, as 2 to 1; the specific heat of Cl diminished by half the difference is $0.792\times0.1214=0.0961$; this specific heat, which corresponds to the molecular mass of Cl, referred to H, gives $3.41\div0.0961=35.5$, the exact weight of tension.

CO^2, $s=0.2164$; $3.41\div0.2164=16$; N^2O, $s=0.2238$; $3.41\div0.2238=15$. In these two cases the fallacy of Avogadro's law is confirmed by the values of specific heat, which would relatively be

smaller for larger weights; according to my deductions, the 2 volumes resulting from a chemical union, and not their half, represent the equivalent of tension; if the specific heat of CO^2 and N^2O, as above quoted, is that of 1 volume, the weight of tension of 2 volumes would involve a diminution of s by 1.41; 0.2164÷1.41 =0.1535; 3.41 ÷ 0.1535=22.21; 0.2238 ÷ 1.41=0.1587; 3.41 ÷ 0.1587=21.5; that is, the specific heat of 2 volumes would correspond very nearly to the actual weight of tension.

CO, s=0.2479; 3.41÷0.2479=13.755; 13.755÷1.41=9.75; the specific heat corresponds in this case to the weight of tension of 2 molecular volumes; the calculated weight of tension of CO being 9.32.

The close connection between specific heat and molecular mass offers a valuable means for the determination of the molecular constitution of allotropic modifications, as in the following cases:

The weight of common phosphorus is 1.82, its sp. h. 0.1887;

$$\frac{1.82}{0.1887} = 9.645;\quad 3\times 3.215 = 9.645$$

" " red phosphorus is 2.18, its sp. h. 0.1698;

$$\frac{2.18}{0.1698} = 12.84;\quad 4\times 3.215 = 12.86$$

" " wood charcoal is 1.8, its sp. h. 0.241;

$$\frac{1.8}{0.241} = 7.47;\quad 2\times 3.735 = 7.47$$

" " graphite is 2.2, its sp. h. 0.202;

$$\frac{2.2}{0.202} = 10.90;\quad 3\times 3.735 = 11.20$$

" " diamond is 3.3, its sp. h. 0.1469;

$$\frac{3.3}{0.1469} = 22.464;\quad 6\times 3.735 = 22.41$$

The equivalent of tension of C is, according to my computation, 1.795; this magnitude increased in proportion to the difference of volumes is $1.795 \times 1.0308 = 1.85$; $2 \times 1.85 = 3.7$, is very near or almost identical with the above multiple of the carbon compounds, 3.735; this coincidence not only discloses the composition of these substances, namely, of charcoal = 4, graphite=6, diamond=12 equivalents, representing respectively 5, $7\frac{1}{2}$, and 15 molecular volumes; but at the same time con-

firms directly the correctness of the computed value of the C molecule.

Further investigation is necessary to decide whether the multiplum of the phosphorus compounds=3.215 represents one or more equivalents. The knowledge gained of the composition of these bodies shows that the true molecular weights of all non-gaseous elements and compounds remain to be established, and that an entire reconstruction and review of all accepted values is involved.

The volume weight of gases, and consequently their specific heat, depend, as is evident, not only on molecular mass and density, but also on atmospheric pressure. Gases whose molecules are of the same weight as that of the atmosphere or its constituents, will expand at the same ratio at all temperatures; but those of greater weight will expand differently at different temperatures. Expansion is proportional to the square of weight; the co-efficients of expansion of gases found by Regnault and others, show an increase with increase of the weights of volume. Consequently will the rate of expansion of heavier gases at lower degrees of temperature, exceed that of the atmosphere; but weight decreasing when expansion increases, the difference of the rate of expansion will lessen at higher degrees of temperature, and disappear when the increase of temperature is sufficient to establish equality of tension between the different gases.

The connection between expansion and specific heat is obvious; expansion being proportional to weight or mass, specific heat is inversely as expansion, and directly as molecular density, and it follows, therefore, 1, from the gradual diminution of weight and expansion at higher temperature, the general well known fact, that the specific heat of all bodies increases with increase of temperature; and 2, that the difference of the rate of expansion between heavier gases and the constituents of the atmosphere involves an increase of specific heat for the former with increase of temperature, which is not the case with the latter; and the cause is thus explained why the specific heat of CO^2 and N^2O increases with temperature, while that of H, N, and O, whose weight is lighter or equal to that of the atmosphere, does not increase at the same rate.

This effect of temperature has probably to be considered in the computation of the exact weights of gases. The weights

found by experiment are all referred to a definite temperature and barometric height; but while H, N, and O will, in relation to each other, remain constant in weight at any change of temperature, CO^2 will, at lower degrees, expand at a greater rate, and consequently be found lighter in comparison with them. The actual weight of carbonic acid is 22; the calculated, 24; future researches must determine whether the difference is actually, wholly or in part, an effect of temperature.

VII. REFRACTION.

In the following the absolute refractive power of gases, as found by Dulong, is compared with the calculated molecular weights; the values of Dulong express units of 0.000001; referred to H they are:

H,	277	=1.000;	molecular weight=	1.000
O,	544	=1.964;	" " =	1.966
N,	601	=2.17;	" " =	1.323
Cl,	1545	=5.578;	" " =	5.831
HN^3,	771	=2.783;	" HN=	2.15
HO,	589	=2.126;	" " =	2.835
CO,	681	=2.46;	" " =	3.053
CO^2,	899	=3.25;	" " =	4.900
HCl,	899	=3.25;	" " =	6.061

The connection between refraction and molecular weights is sufficiently manifest in the case of O and Cl. N=2.17 is the weight of an unit of volume under atmospheric pressure, for $14 \div 3 = 4.66$; $\sqrt{4.66} = 2.16$. The smaller molecular weight of N is by atmospheric pressure increased to a greater extent than that of O; the increase is, with relation to the N molecule, at the rate of $1.323 \div 2.316 = 0.571$; $1.571 \times 1.323 = 2.078$. In consequence of difference of volume, the computed value=1, is increased to 1.0365, and $2.078 \times 1.0365 = 2.154$, gives very nearly the value of refraction.

As the calculated values of the compounds represent magnitudes not identical with the adopted weights of equal tension,

which are the base for the determination of the powers of refraction, no exact correspondence can be expected; but the discrepancies can be traced to the error of Avogadro's law.

The refractive power of 1 volume of CO^2=3.25, would be 1.41× 3.25=4.58, if the weight of 2 volumes had served as a base; and this figure is not very far from 4.9, the molecular weight. For HCl the value of refraction is exactly the same as that of CO^2, while the molecular weights differ by 1.41; for HCl=6.061÷1.41 =4.3, which is approximately the value of the power of refraction of 2 volumes of CO_2.

I find in Mr. Wm. Crookes' determination of the viscosity of gases at low degrees of pressure, obtained by means of the radiometer, a close agreement with the molecular weights of the gases.

The logarithmic decrease is:

At atmospheric pressure	for H=0.063	for O=0.126
" 0.000250^{mm} "	" " =0.057	" " =0.111
" 0.000100 " "	" " =0.052	" " =0.105
" 0.000050 " "	" " =0.046	" " =0.093

The values of O being in all cases almost exactly the double of those of H. (*Chem. News*, Dec. 29, 1876.)

Should not the radiometer prove a valuable auxiliary in the determination of the exact molecular weights of other substances, many of which not volatile at atmospheric pressure, are undoubtedly so in vacuo?

So far the substance of the evidence which I have to produce. I have been able not only to show the exact agreement of the calculated with the established molecular weights, but to refer the most diversified phenomena of different branches of the physical sciences to one great common cause; to explain in a simple and unrestrained manner, without encountering any conflicting evidence, the most obscure and complex facts of chemistry, and to demonstrate the solid foundation which underlies all the chemical processes and laws established experimentally as matters of fact.

The ground which it has been necessary to go over is so vast,

involving in fact the very fundamental principles of all science, the details bearing on the results of my determinations, and consequently the possibilities of error so numerous, that it would be presumptuous to accept as final the values obtained by me. The agreement of facts and figures is, however, so abundant and complete, the evidence so conclusive and corroborating in all departments, that neither error, nor chance and accident can possibly account for them, and the general confirmation of my essential propositions is, I think, only a question of time. I sum them up as follows:

1. The non-existence of an hypothetical ether.

2. The almost infinite but sharply defined divisibility, atomic constitution, omnipresence and unity of matter.

3. That the perpetual motion of the discreet particles of matter is the source of all force, of gravity, chemical action, etc.

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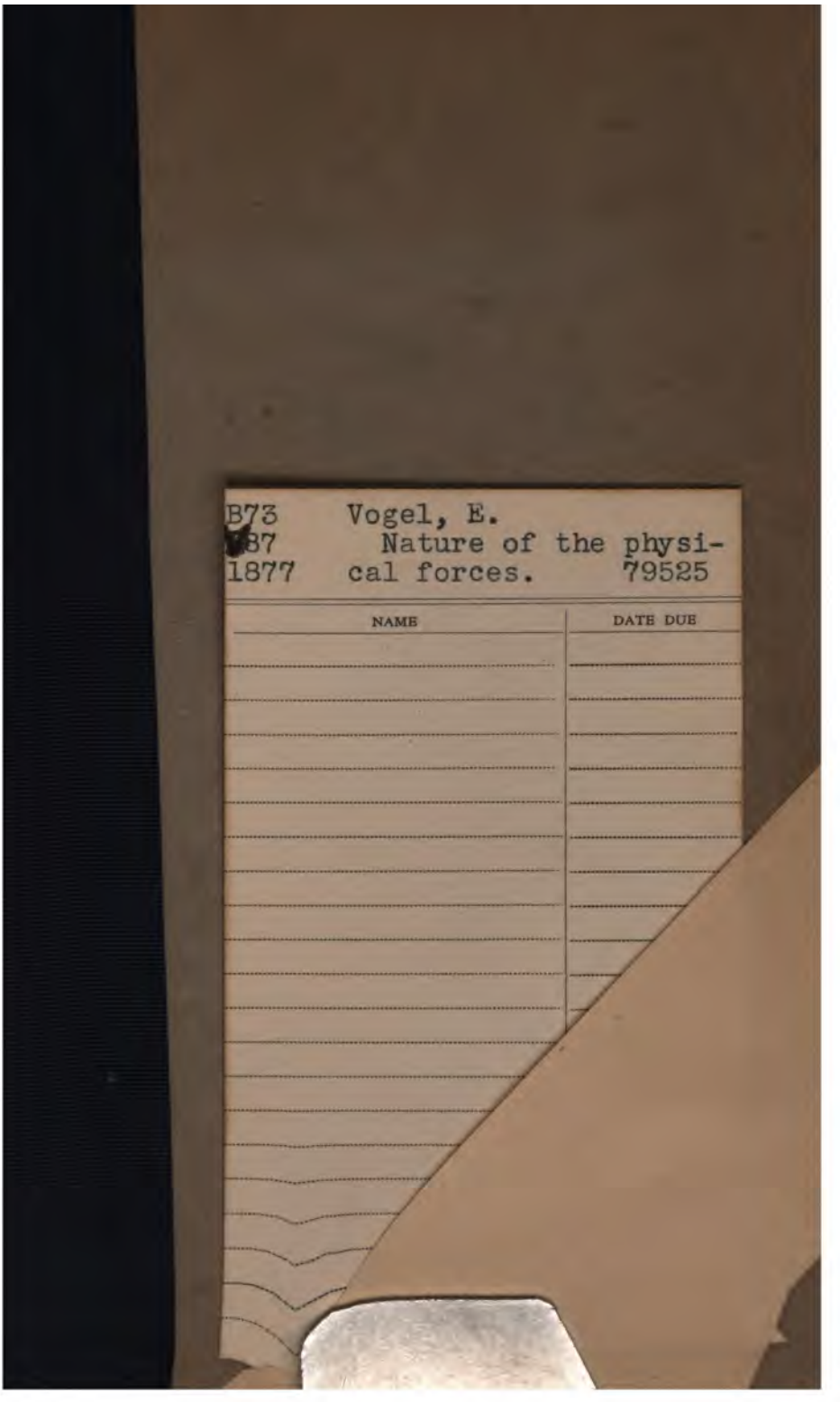
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